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ON THE RELATION OF MOISTURE IN AIR TO HEALTH AND COMFORT.

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In continuation of the paper read before the American Institute of Architects,[1] which has appeared in the three previous numbers of this Journal, it is desirable to support the argument for the impracticability of attaining the full summer condition of humidity, for air in winter which has been warmed to the temperature of comfort, by more extended computations than could be presented to an audience, or brought within the scope of comprehension of the listener or the casual reader. The single example with specified relations, which was taken, showed, on calculation, that nearly as much heat would be expended in supplying vapor for the usual hydration of air of usual humidity and of 34° temperature (which air was heated to 70°), as was expended in heating the air itself.

The temperatures, and humid condition of about 69 per cent. assumed, being the averages of nature, out of doors, for three warm or three cold months, in the city of Philadelphia, in 1844, as reported by Prof. Bache. It occurs, accidentally, that the exact conditions of temperature and humidity chosen for an example, give the ratio of heat demanded for the two purposes incident to warming air as unity, while this ratio, for other temperatures and degrees of humidity, will be found to vary materially. For the purpose of exhibiting more completely the general case, the accompanying table has been prepared to show what quantities of heat are demanded for heating, or are given out in cooling air of 70 per. cent. humidity, from various temperatures (from 0° to 100°) to 70°, in direct comparison to the quantities for vaporization or condensation of water to procure the condition of 70 per cent. humidity to the air of 70°. When 70° and 70 per cent. humidity may be accepted as the American summer condition of comfort for the air; it being asserted that 70°, with 80 per cent., or more, of humidity, is close and enervating, while 70°, with 60 per cent., or less, of humidity, is fresh and cool, and demands heavy clothing to preserve the comfort of the individual—a proper and necessary demand in winter.

[1] At the Meeting of the Institute at Boston, October 18th, 1877.

Table.

VOLUME AND WEIGHTS OF AIR AND VAPOR OF HUMIDITY—TEMPERATURES OF SATURATION AND DEW POINT—HEAT TO BE EXPENDED IN WARMING OR COOLING AIR OR VAPOR TO THE TEMPERATURE OF 70° FAHRENHEIT AND CONDITION OF 70 PER CENT. HUMIDITY.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.
Temperatures in degrees, Fahrenheit.	Volume of dry AIR to one Pound. Barometer 29·922 inches.	Weight of dry AIR per 1000 cubic feet. Barometer 29·922 inches.	Force of VAPOR in inches of Mercury Column.	Weight of VAPOR in 1000 cubic feet = quantity of Vapor in saturated Air.	70 per cent. of weight of VAPOR in 1000 cubic feet = quantity of Vapor in air of 70 per cent. humidity.	Weight of 1000 cubic feet of AIR of 70 per cent. humidity, including its vapor. Barometer, 29·922 inches.	Weight of dry AIR in 1000 cubic feet of Air of 70 per cent. humidity. Barometer. 29·922 inches.	Weight of VAPOR accompanying 73·63 lbs. of dry air at given temp., and 70 per cent. humidity. Barom., 29·922 in.	Percentage of volumes of AIR of 70 per ct. humidity displaced by the presence of aqueous vapor. Barom., 29·922 in.	Temperatures of Saturation in degrees Fahr. = Dew Point of AIR of various temperatures, and 70 per ct. humidity.	Temperature of indication of Wet Bulb Thermometer, taken from Glaisher's tables.	Weight of VAPOR to be supplied or taken from 1000 cu. ft. of Air, when brought to 70° Fahr. to make quantity needed for 70 per cent. humidity.	Heat units for warming or cool'g 0·07363 lbs. of AIR with its accompanying vapor from given temp. to 70° Fahr.	Heat units demanded for vaporization or condens. of vapor to give 70 per ct. humidity to one cu. ft. of AIR of 70° F.
0	11·577	86·38	0·045	0·081	0·057	86·35	86·29	0·048	0·11	......	......	0·749	1·228	0·797
5	11·704	85·44	0·054	0·095	0·067	85·40	85·33	0·058	0·13	......	......	0·739	1·141	0·787
10	11·830	84·53	0·067	0·118	0·082	84·48	84·40	0·072	0·16	1·1	8·8	0·725	1·054	0·772
15	11·957	83·64	0·085	0·148	0·104	83·58	83·47	0·092	0·20	7·3	13·9	0·705	0·966	0·751
20	12·083	82·76	0·108	0·186	0·130	82·68	82·55	0·116	0·25	12·4	18·9	0·681	0·879	0·725
25	12·210	81·90	0·136	0·232	0·162	81·80	81·64	0·146	0·32	17·2	23·5	0·651	0·792	0·693
30	12·336	81·06	0·169	0·285	0·199	80·94	80·74	0·182	0·40	21·8	27·7	0·615	0·704	0·655
32	12·387	80·73	0·183	0·308	0·216	80·60	80·38	0·198	0·43	23·6	28·8	0·599	0·670	0·638
35	12·463	80·24	0·207	0·345	0·242	80·10	79·85	0·223	0·49	26·5	25·	0·574	0·617	0·611
40	12·590	79·43	0·251	0·415	0·290	79·26	78·96	0·271	0·59	30·8	30·1	0·526	0·529	0·560
45	12·716	78·64	0·302	0·494	0·346	78·43	78·08	0·326	0·71	35·5	34·6	0·471	0·432	0·501
50	12·843	77·87	0·362	0·587	0·411	77·62	77·21	0·392	0·85	40·3	45·	0·405	0·353	0·432
55	12·969	77·11	0·433	0·695	0·487	76·82	76·33	0·470	1·01	45·1	49·	0·328	0·266	0·349
60	13·096	76·36	0·517	0·821	0·575	76·02	75·44	0·561	1·21	50·0	54·	0·236	0·178	0·251
65	13·222	75·63	0·616	0·968	0·678	75·22	74·54	0·669	1·44	54·9	58·5	0·127	0·088	0·136
70	13·349	74·91	0·732	1·138	0·797	74·43	73·63	0·797	1·71	59·8	63·	0·000	0·000	0·000
75	13·476	74·21	0·867	1·336	0·935	73·65	72·71	0·946	2·03	64·7	68·	0·149	0·090	0·159
80	13·602	73·52	1·023	1·562	1·094	72·86	71·77	1·121	2·39	69·5	72·5	0·324	0·181	0·345
85	13·729	72·84	1·203	1·822	1·275	72·07	70·80	1·326	2·82	74·2	77·5	0·529	0·272	0·563
90	13·855	72·17	1·410	2·117	1·482	71·28	69·80	1·563	3·30	78·9	82·5	0·766	0·365	0·816
95	13·982	71·52	1·647	2·452	1·716	70·49	68·77	1·837	3·85	83·7	87·5	1·040	0·460	1·108
100	14·108	70·88	1·918	2·828	1·980	69·69	67·71	2·152	4·49	88·4	92·5	1·355	0·556	1·443

The figures relating to weights in the foregoing table, refer to 1000 cubic feet (a cube of 10 feet side) for a unit, to avoid the repetition of 0's in decimals; by multiplying any value by 7, the weights per cubic foot in grains will be found. All the weights are in pounds avoirdupois and decimals. The volumes are in cubic feet.

Columns II and III are derived from Regnault's data ; weight of one cubic foot of dry air = 0·080728 pound = 12·387 cubic feet per pound; and rate of expansion = 0·002039 volume for each degree Fahrenheit from 32° = 0·025315 cubic foot per pound from 32°.

Column IV is taken from Guyot's tables, Regnault's data, slightly corrected by differences.

Column V is derived from $W = \frac{0·622}{29·922} \times$ value of Column III $\times$ value of Column IV, where 0·622 = specific gravity of vapor in air of the same tension; and 29·922 = inches of mercury column which measures the tension of air in Column II.

Column VI is obtained directly from Column V, as indicated in caption.

Column VII is obtained by taking the difference of weight of the volume of vapor in the air, from that of the air which it displaces, and deducting their difference from the respective values in Column III. The values in Column VII agree as closely as could be expected with results in Glaisher's tables.

Column VIII is obtained by deducting weight of vapor, Column V from Column VII.

Column IX is obtained by taking the ratio of quantity of dry air in the several values of Column IX, with the value at 70° (= 73·63 pounds) as a unit, and dividing by this ratio the values in Column VI.

Column X is obtained by taking 70 per cent. of $\frac{F}{29·922}$, where F is the tension of vapor possible to exist at the given temperature, as given in Column IV, and 29·922 is the tension of the atmosphere. It should be noticed that this column has its units in percentages: the first value, for instance, is $\frac{11}{100}$ of a per cent.

Column XI is obtained by making a computation of three columns for saturated air, like VII, VIII and IX, and thus ascertaining at what degree of temperature the values in Column IX coincide with those in the same column for saturated air. This column closely agrees with Glaisher's, varying two degrees higher at 15° and corresponding at 80°.

Column XII is taken from Glaisher's tables at 70 per cent., and is sufficiently exact for use.

Column XIII is obtained by taking the difference between the quantity of vapor in air of 70° Fahrenheit, and that in the several values given in Column IX.

Column XIV is obtained by multiplying 0·07363 pounds (the quantity of dry air in a cubic foot of air of 70° Fahrenheit and 70 per cent. humidity) by 0·238 (the specific heat of air), adding to this value, that of the amount of the several values in Column IX, multiplied by 0·475 (the specific heat of vapor), and then multiplying the sums of the above by the number of degrees from 70° which the air is to be heated or cooled.

Column XV is obtained by multiplying the values of Column IX (the vapor to be supplied or removed) by 1065° = the latent heat of steam from and at 70°, and dividing the result by 1000, so as to give the heat of vaporization belonging to one cubic foot of air at 70°.

A careful study of the table, with comparisons of the values given in the several columns, will readily allow any student to find the fullest corroboration of the views expressed in the original paper; but for the convenience of the general reader, it may be well to exhibit some of the results. Thus, calling attention to Column XI, it will be seen that the air of saturation at 60° becomes, by heating, that of 70° and 70 per cent. humidity; showing a close approach of English and American humid conditions to the comfortable condition in either case. Again, the temperature of saturation for air of 80°, with 70 per cent. humidity, is 69·5°; consequently, air of above 80° of the usual humid condition of our climate in summer, will become a mist and rain, unless its moisture be absorbed by some non-heat-giving absorbent. If such air is to be reduced to the 70° standard of comfort, by means of surfaces cooled by currents of water, such surfaces must have a temperature at least below 60°, and probably 10° below that point, to abstract, by condensation, the moisture from the air. The heat demanded for condensation, therefore, will be increased some 20° below that of cooling the air, but as the latent heat of vapor of water is nearly constant, the difference of quantity of heat for cooling is not materially changed.

A study of the last two columns will demonstrate that as the quantity of moisture present in air falls off much more rapidly than the temperature, the quantity which is requisite to make up the moisture in air at 70° and 70 per cent. humidity, from the condition at the various temperatures with the same ratio of humidity, becomes more and more nearly the same as the temperatures fall off. The great heat demanded for changing water into vapor accordingly, is nearly constant for the low temperatures, and the heat demanded for warming air gains on that for vaporization of water; and after passing a greatest difference at between 55° and 60°, attaining an equality at about 36°, it becomes about one-half greater at 0°.

The tabular values here given have, it is thought, been first grouped together in this, or any form, and they will be found a ready and convenient basis for the application of the various meteorological conditions to warming and ventilation.